National Defense Industrial Association

7th Annual Systems Engineering Conference

What is the government (DCMA) looking for on programs…

And just how do they predict acceptable progress

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DCMA in Brief

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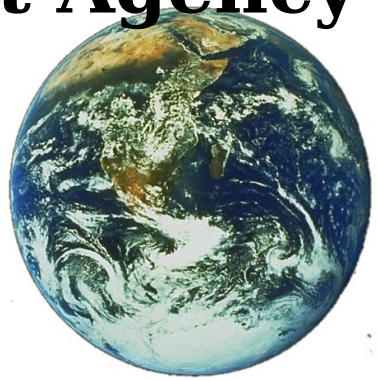
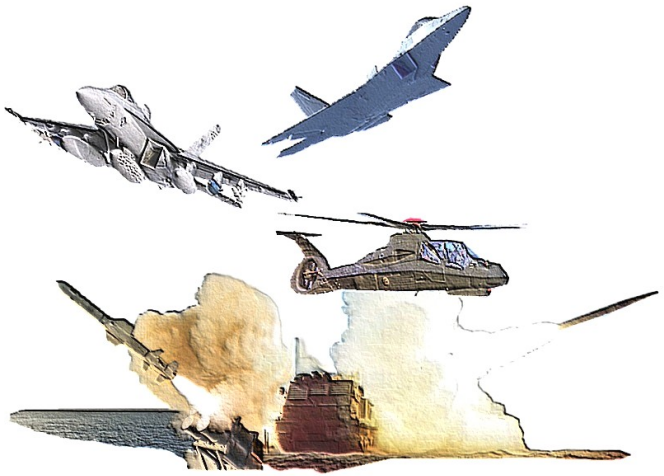


Scope of work

- ***All major weapons system programs***
- ***$860B in Contract "Face Value"***
- ***$116B Unliquidated Obligations***
- ***320,000 Contracts***
- ***19,000 Contractors***
- ***F***

Ai



Span of Control

- ***10,635 Professionals***
- ***800 Locations Worldwide***
- ***60 Major Field Commands***
- ***$81M Reimbursable Foreign Military Sales***

Overview

The government (DCMA) is looking for…

- **A plan**
  - ***Work Breakdown Structure***
  - ***Technical Performance Measures (TPMs)***
  - ***Technology Readiness Levels***
  - ***Organizational Management***
  - ***Process Capability***
  - ***Quality Requirements***

- **A way to tell if the plan is good**

- **Performance to the plan**

What happens when BIG programs go bad?

- **Invariably, "they" say there was, and is, a problem with systems engineering …"they" being:**
  - ***Tri-Service Assessment Initiative™ (TAI)***
  - ***NDIA***
  - ***And others***

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Tri-Service Assessment found …

- **Sixty one percent of the programs they reviewed had Systems Engineering (SE) issues.**[1]
  - Non existent System Engineering
  - Poor System Engineering implementation
  - Lack of System Engineering experience
  - Dispersion of System Engineering Responsibility
  - System Engineering inadequate for program requirements

What type of SE program do you have?

DoD Commissioned NDIA Study

- **The top five issues were**:
  - Lack of awareness
  - Lack of qualified people
  - Insufficient SE tools
  - Requirements definition, development, and management not performed effectively
  - Poor initial program formulation

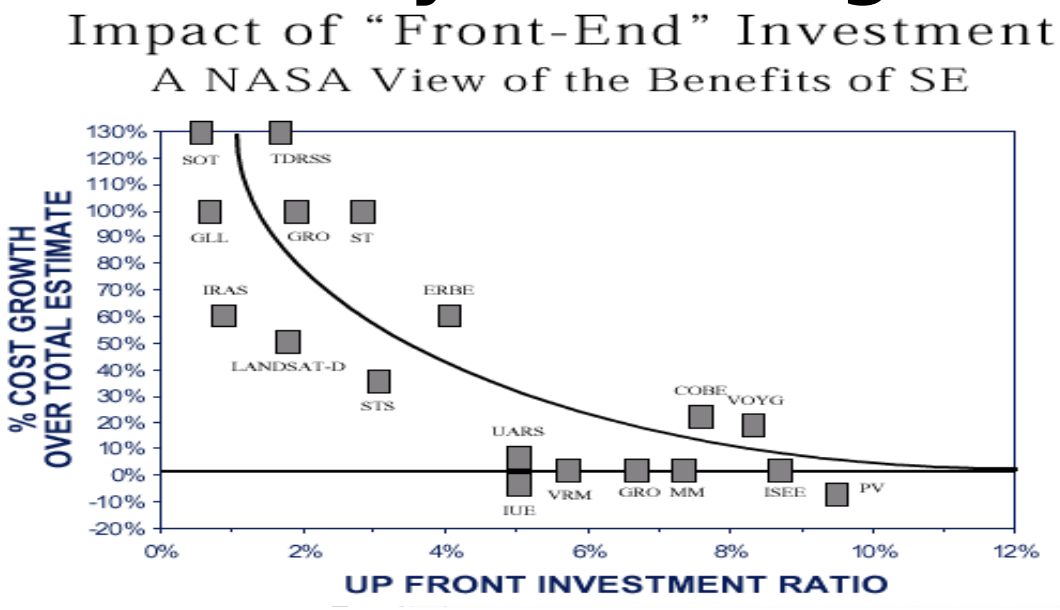
How do we improve the Systems Engineering effort being expended on a

How much SE do we need?

- We will look at the following:
  - NASA Model
  - Systems Engineering Center Of Excellence Model (SECOE)
  - Constructive Systems Engineering Cost Model (COSYSMO)
  - Two Complexity Models

Stressing the need for good SE

- How much is needed?
  - NASA study showed programs are less likely to experience cost and schedule overruns when at least 5% to 10% of program funds are allocated to systems engineering



SECOE Study on 25 Projects[2]

- **Showed cost and schedule risk is reduced by 2/3 when systems engineering effort (SEE) is 15% of actual costs versus 1% of actual costs.**

SE Effort = SE Quality = SE Cost / Actual Cost

Actual Cost is up to delivery of first a

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COSYSMO[3]

- Will estimate systems engineering costs
- Looks at four size drivers with complexity as one weighting factor:
  - System requirements, major interfaces, operational scenarios, critical algorithms
- … and 14 cost drivers, three of which are:
  - Architecture complexity, technology maturity, and process maturity
- According to the model, process maturity can be per the Capability Maturity Model Integrated (CMMI™)

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Complexity Matters Most

- Ernstoff (Raytheon) accurately estimated SE resources and found system complexity was the dominant parameter.[4]
- Mog and Thomas studied 18 NASA programs and accurately estimated program costs by measuring program complexity.[5]

So, complexity analysis can lead to accurate

DCMA Approach to SE Management

DCMA Approach to SE Management

- **Can cost and complexity models help us to understand program/SE requirements earlier?**

- **Can TPMs help us predict performance?**
  - Compares estimated or actual technical performance to planned performance **(when a planned profile is used)**

- **Can Technology Readiness Levels (TRLs) be used to predict future progress?**

- **Is process maturity (CMMI) an indicator**

Design Complexity Levels

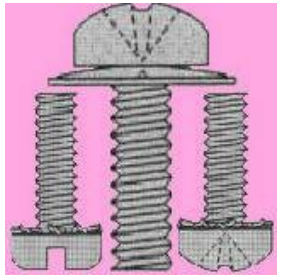
DCMA has recognized the importance of complexity and will take it into consideration as we address the government's risk during design and development

5. High

4. Moderate/High

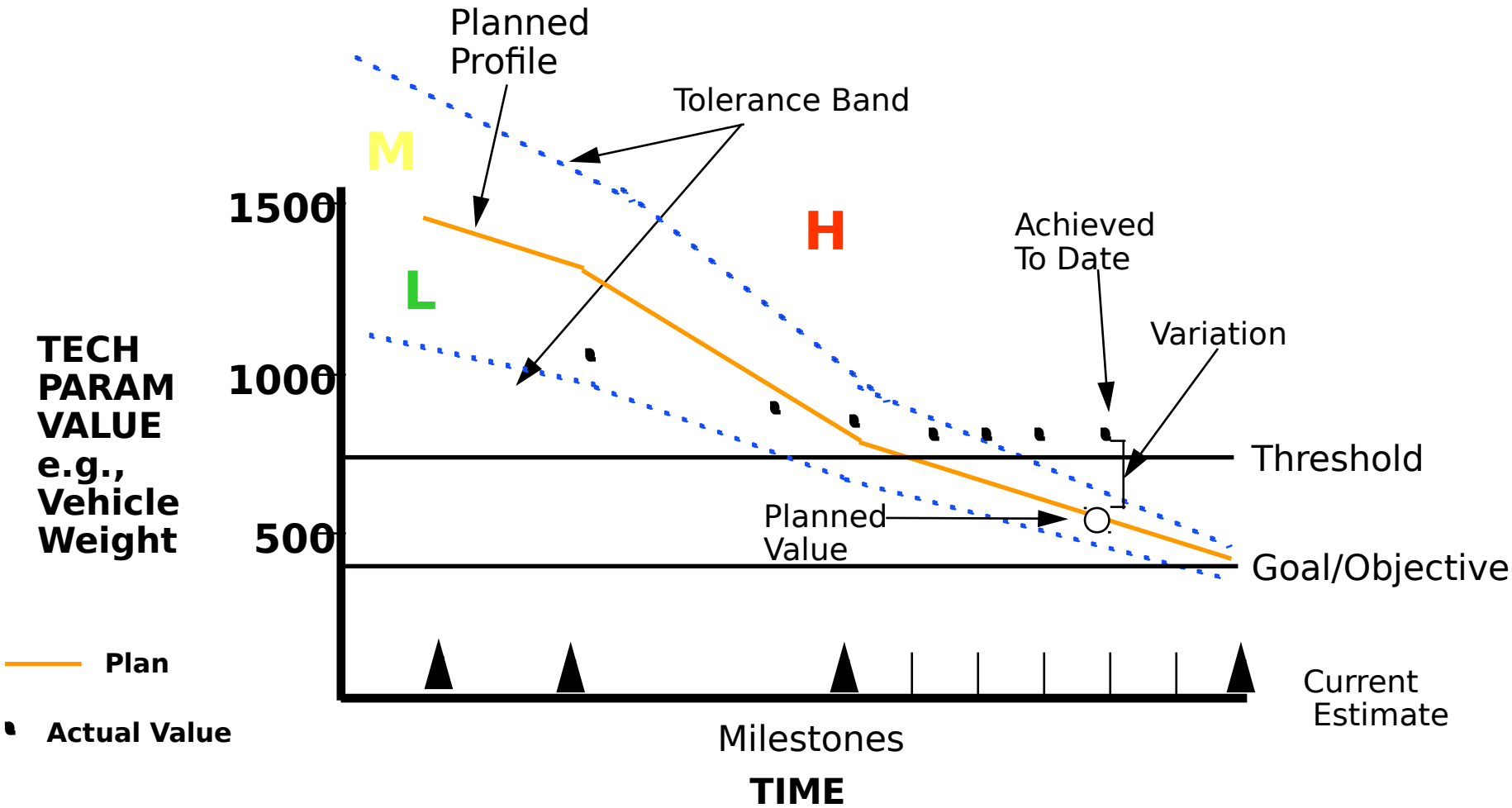
3. Moderate

2. Low/Modera



1. Uncomplicated

Technical Performance Measurem



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TECHNOLOGY READINESS LEVELS AND THEIR DEFINITIONS

GAO Studies have shown that TRLs of 1-6 have had cost and schedule overruns of 60-120%. Low TRL are sometimes associated with evolutionary/risk driven prototypes and spiral development[6]

Technology Readiness Level	Descriptions
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory

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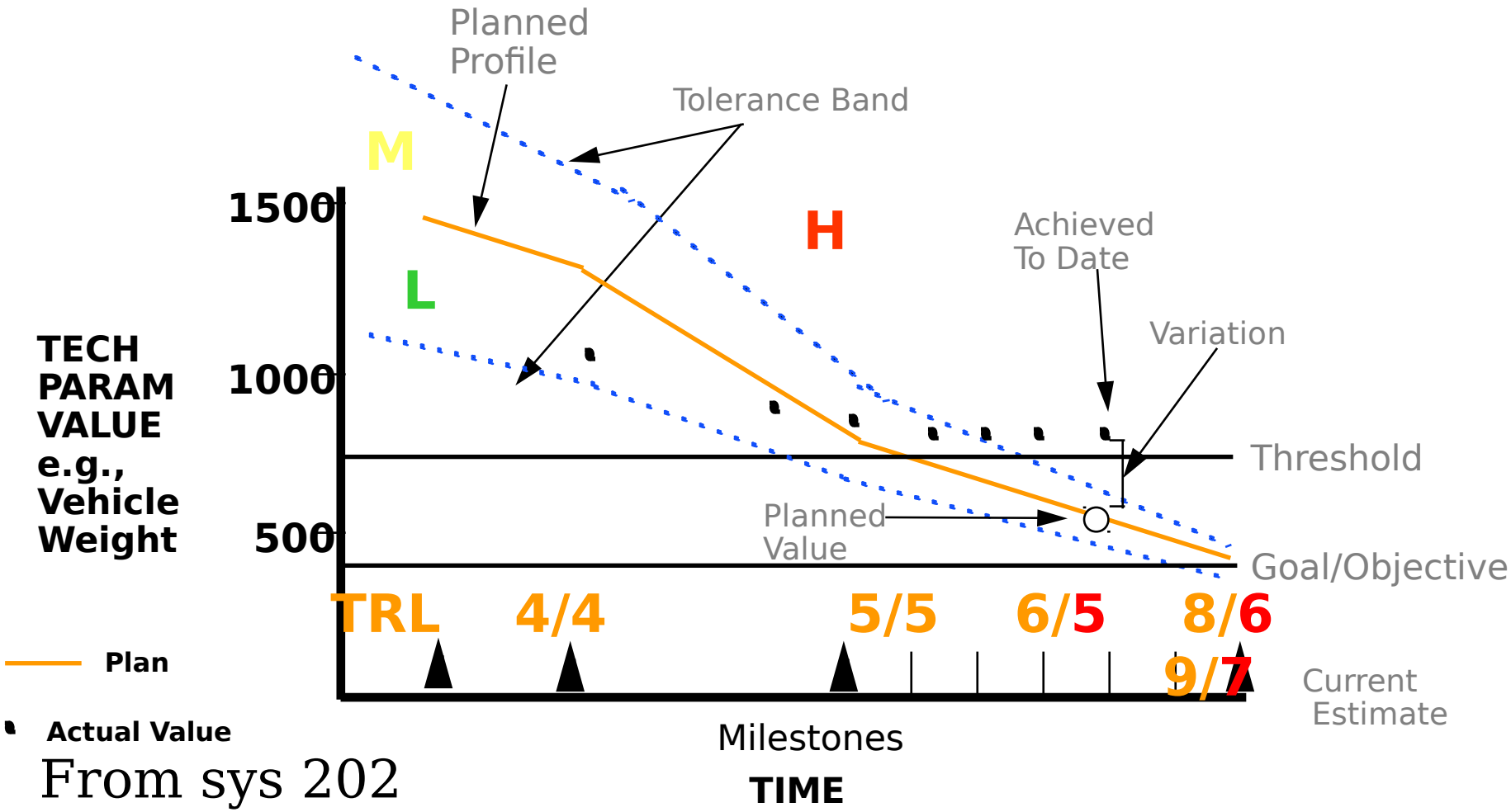
TECHNOLOGY READINESS LEVELS AND THEIR DEFINITIONS

GAO studies have also shown that TRLs of 7-9 have had cost and schedule overruns near 0%.

Technology Readiness Level	Descriptions
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system "flight proven" through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.

This GAO report concluded "technology maturity can be measured and its consequences for products can be forecast."

Technical Performance Measurem



From sys 202

TAI Systemic Analysis White Paper[7]

- **Process Capability, Adherence & Performance**
  - ***"It is not an exaggeration to state that process performance shortfalls are seriously impeding successful program execution."***
  - ***"… nine out of every ten DoD programs assessed by TAI exhibit these process performance shortfalls."***
  - ***"Software intensive programs should be encouraged to assess their program team's process capability."***

Plans for CMMI Usage

- CMMI is a tool to enhance program insight and improve systems engine et al
  - Consists of specific and generic pract organized by process area
  - Support Predictive Analysis
  - Aids Variance Analysis
  - Aid Risk identification, handling and monitoring
  - Not about supplier attaining “Maturity Level” rating

- Need right balance of “process” and “product”

CMMI Categories and Process Areas

Category	Process Area
Project Management	Project Planning Project Monitoring and Control Supplier Agreement Management Integrated Project Management(IPPD) Integrated Supplier Management (SS) Integrated Teaming (IPPD) Risk Management Quantitative Project Management
Support	Configuration Management Process and Product Quality Assurance Measurement and Analysis Causal Analysis and Resolution Decision Analysis and Resolution Organizational Environment for Integration (IPPD)
Engineering	Requirements Management Requirements Development Technical Solution Product Integration Verification Validation
Process Management	Organizational Process Focus Organizational Process Definition Organizational Training Organizational Process Performance Organizational Innovation and Deployment

Process Analysis Using CMMI

Prototype Integrated Spreadsheet

WBS Number							CMMI PAs														Metrics						
L1	L2	L3	L4	L5																							
100000																											
	120000																										
		122000																									
			122100																								
				122110	Y	1	1	1		1												3	H			1.13	1.00
				122120	N	2				1												3	H			0.74	1.00
				122130	Y	1	1		1													3	H			1.68	0.84
				122140	N	2	1								1							3	H				
				122150	Y	1		1								1	1					3	H			1.03	1.02
				122170	N	2		1				1	1		1		1					3	H			0.90	0.95
				122180	N	3	1	1								1						3	H			0.98	0.96
				122190	N	3		1											1			3	H			1.21	1.00
			122200		N	3	1								1	1	1					4	M			1.00	1.00
			122400		N	3		1								1	1		1			5	M			1.10	1.00
		123000			N	2																6	L				
						Process Area Hits	5	6	1	2	0	1	1	0	3	4	4	0	2	0							
						Weighted PA Priority = SUM(WBS Priority x PA Influence)	10	13	1	3	0	2	2	0	7	10	9	0	6	0							
						CMMI Appraisal Results																					

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What's Next?

- **Combining all our previous and current efforts in an integrated predictive analysis approach**
  - ***Includes EV, Systems Engineering, CMMI, Software, Quality and other DCMA functions***
  - ***Using the Integrated Spreadsheet which includes WBS, process capability, complexity level, TRL, TPMs, EV, critical path, and systems engineering effort. Will allow for both a quantitative and qualitative program assessment.***
- **Continuing CMMI pilot to institutionalize and validate DCMA's CMMI method**

Summary

- **Looking for a good plan that also addresses SE needs**
  - Does it reflect an awareness of the need for systems engineering commensurate with program complexity?
  - Is the systems engineering process properly resourced, mature, and properly executed?
  - Does the plan reflect intimate know
    technical effort at the IBR?
- **Performance to plan**
  - Do TPMs and TRLs show sufficient progress?
  - Does the integrated assessment of WBS, CMMI, EV, and technical

Make it so!

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References

1. Tri-Service Assessment Initiative Phase 2 Systemic Analysis Results – Conference on the Acquisition of Software Intensive Systems, January 2003
2. Value of Systems Engineering – SECOE Research Project Progress Report, INCOSE, 2002, Honour and Mar
3. Constructive Systems Engineering Cost Model, July 2003, PSM Conference, Boehm, Reifer, and Valerdi
4. Estimation of System Complexity, Raytheon Systems, April 2001, Michael Ernstoff
5. A Quantitative Metric of System Development Complexity: Validation Results, INCOSE, 1998, Thomas and Mog
6. Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes NSIAD-99-162 July 30, 1999
7. Roots of Failure: Technical and Management Process Shortfalls in DoD Software Intensive Systems, June